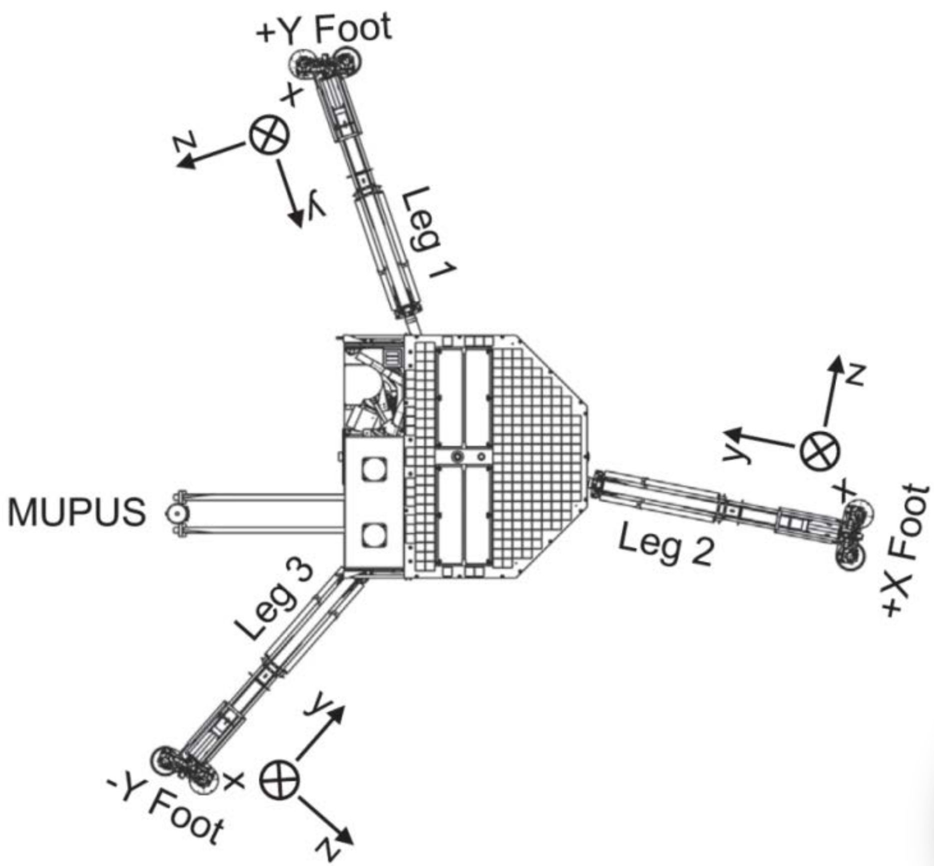
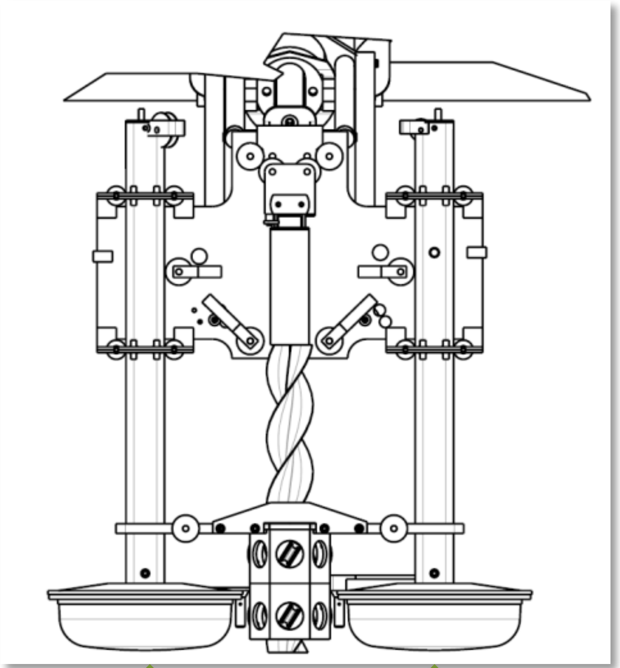
Seismology on Comets

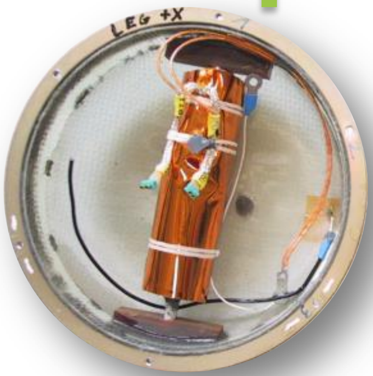
Martin Knapmeyer, for the SESAME Team of Rosetta

DLR

SESAME - CASSE

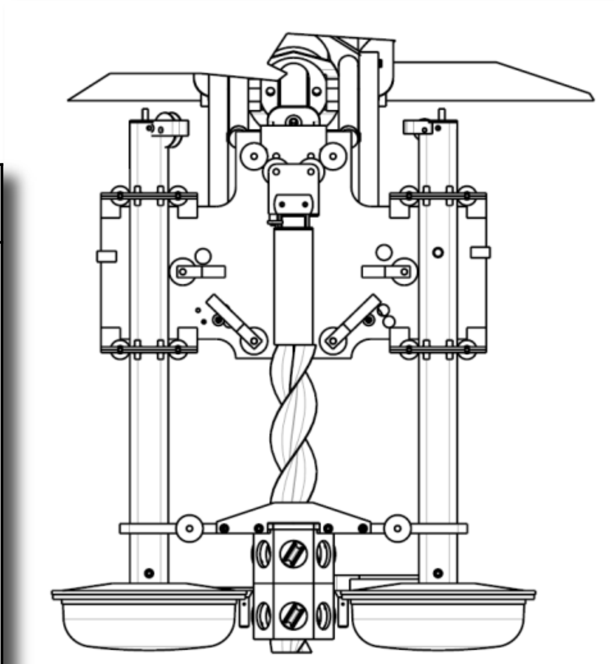


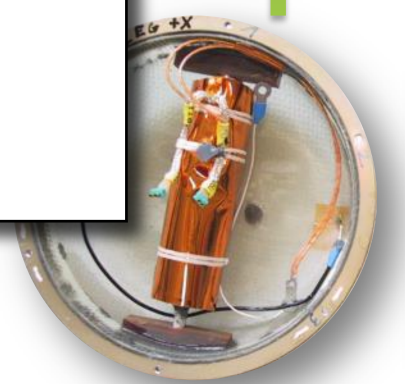




SESAME - CASSE

Receiver Parameters	
Sensor Type	Piezo-Electric Accelerometer
Model	Bruel & Kjaer OrthoShear 4506
Channels	3
Mass	approx. 20 g
Size	17 by 17 by 17 mm^3
Amplitude Range	0.0054 ... 230 ms^{-2}
Frequency Range	1 Hz ... 3.5 kHz (vertical: 6 kHz)
Sampling Rate	0.1 ... 16 kHz (usually 2 - 5 kHz)
ADC	7 Bit + sign, log compression
FIFO RAM	128 kB



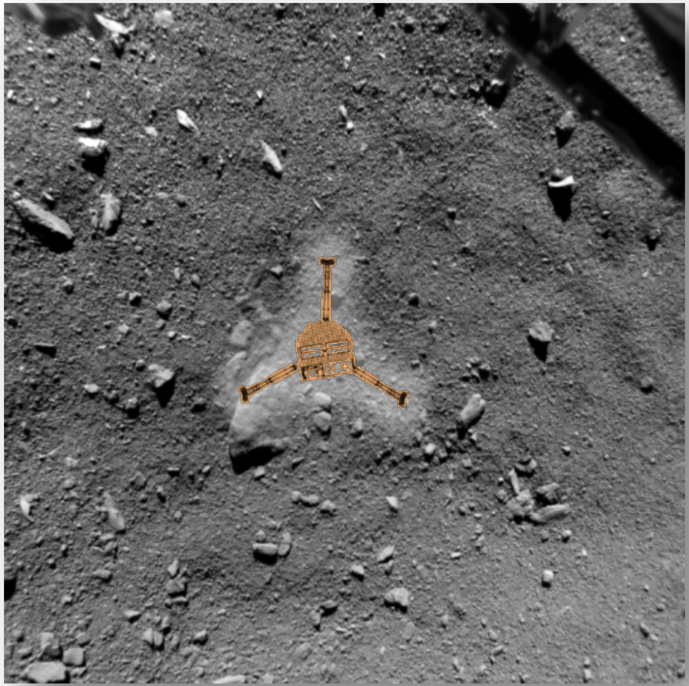


Touchdown in Agilkia

ESA/Rosetta/Philae/ROLIS/DLR

ROLIS, 9 m above ground

Touchdown in Agilkia



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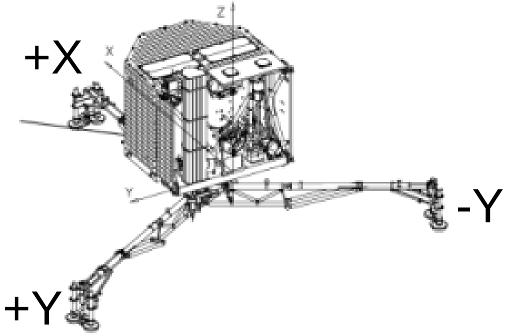
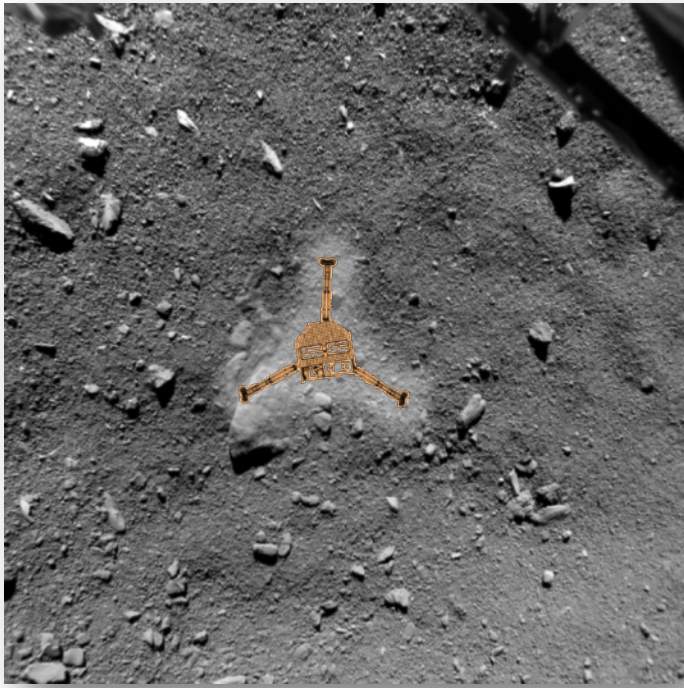
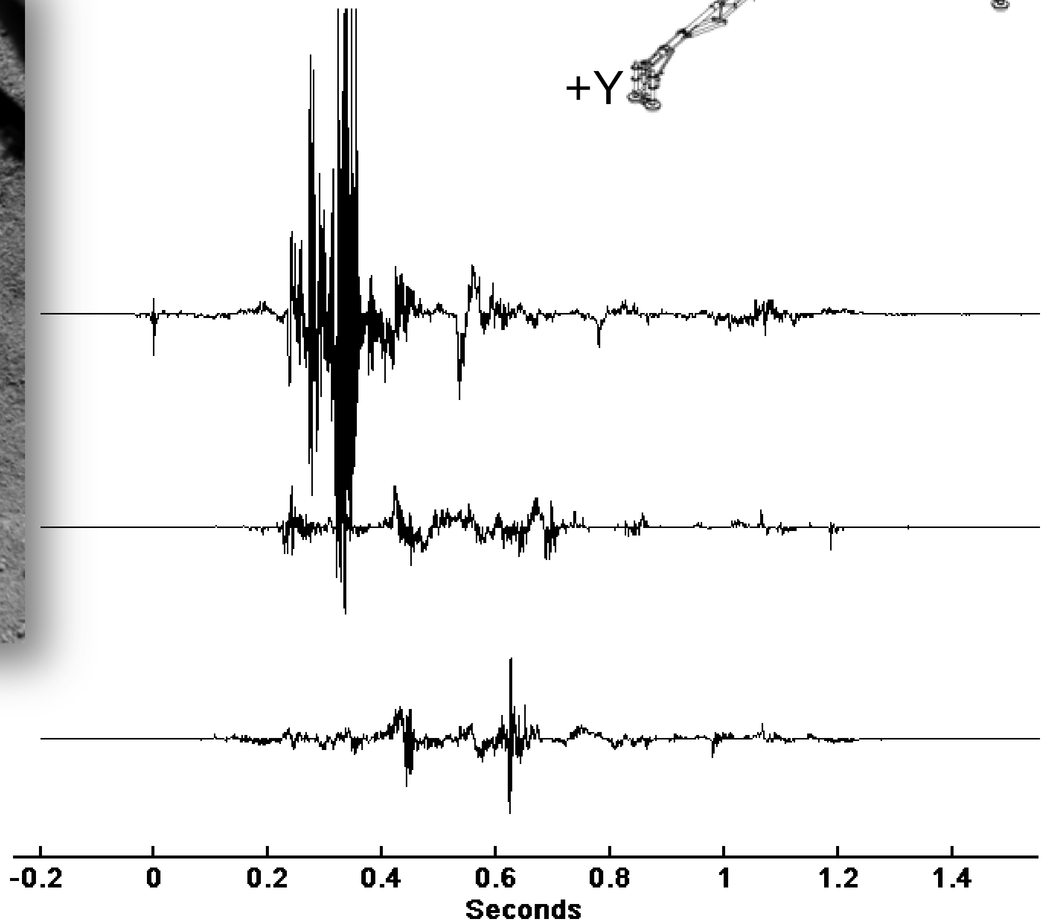
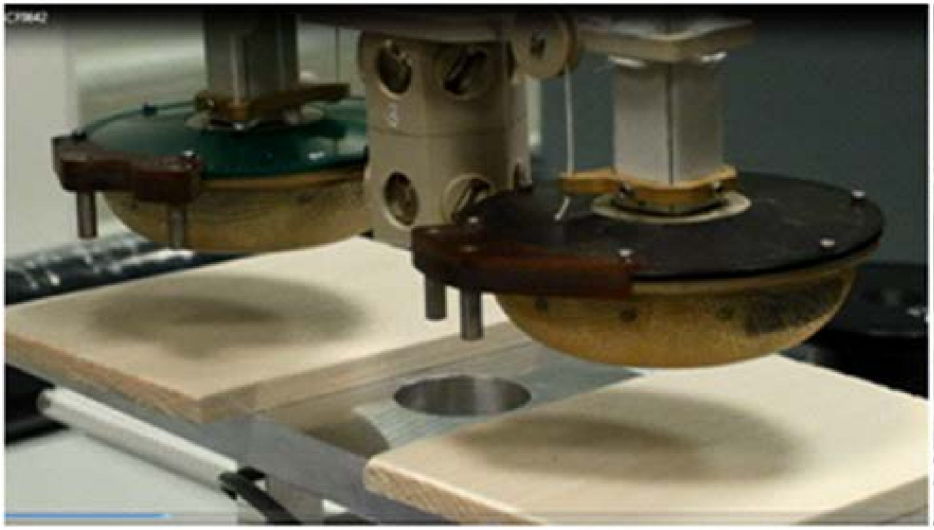


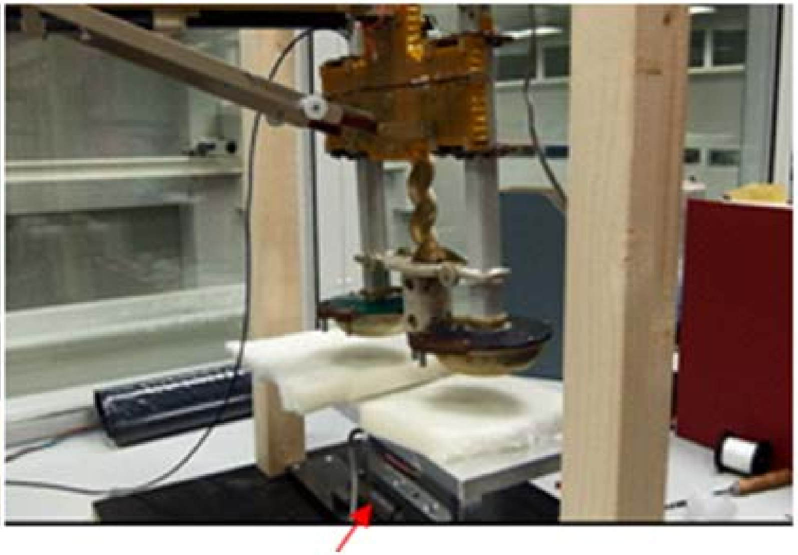

ESA/Rosetta/Philae/ROLIS/DLR

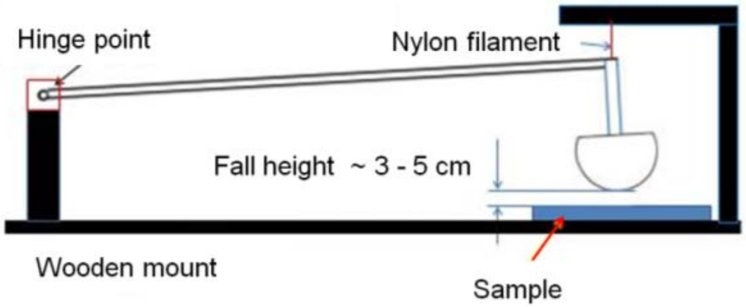
ROLIS, 9 m above ground



Touchdown Lab Tests







Preliminary results for Agilkia:

- Young's modulus: few 10 MPa
- compressional strength: ca. 10 kPa

MUPUS Listening at Abydos

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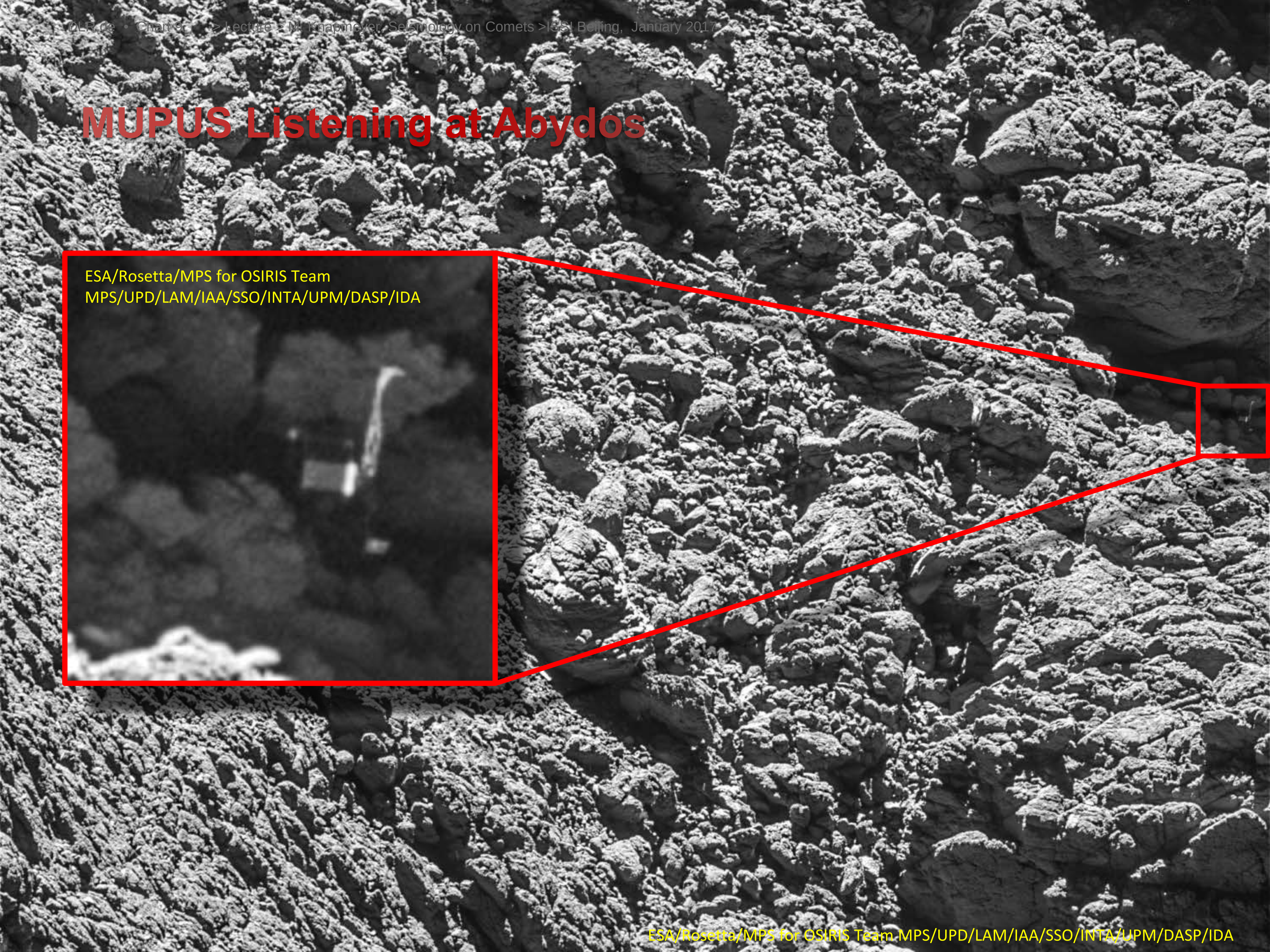

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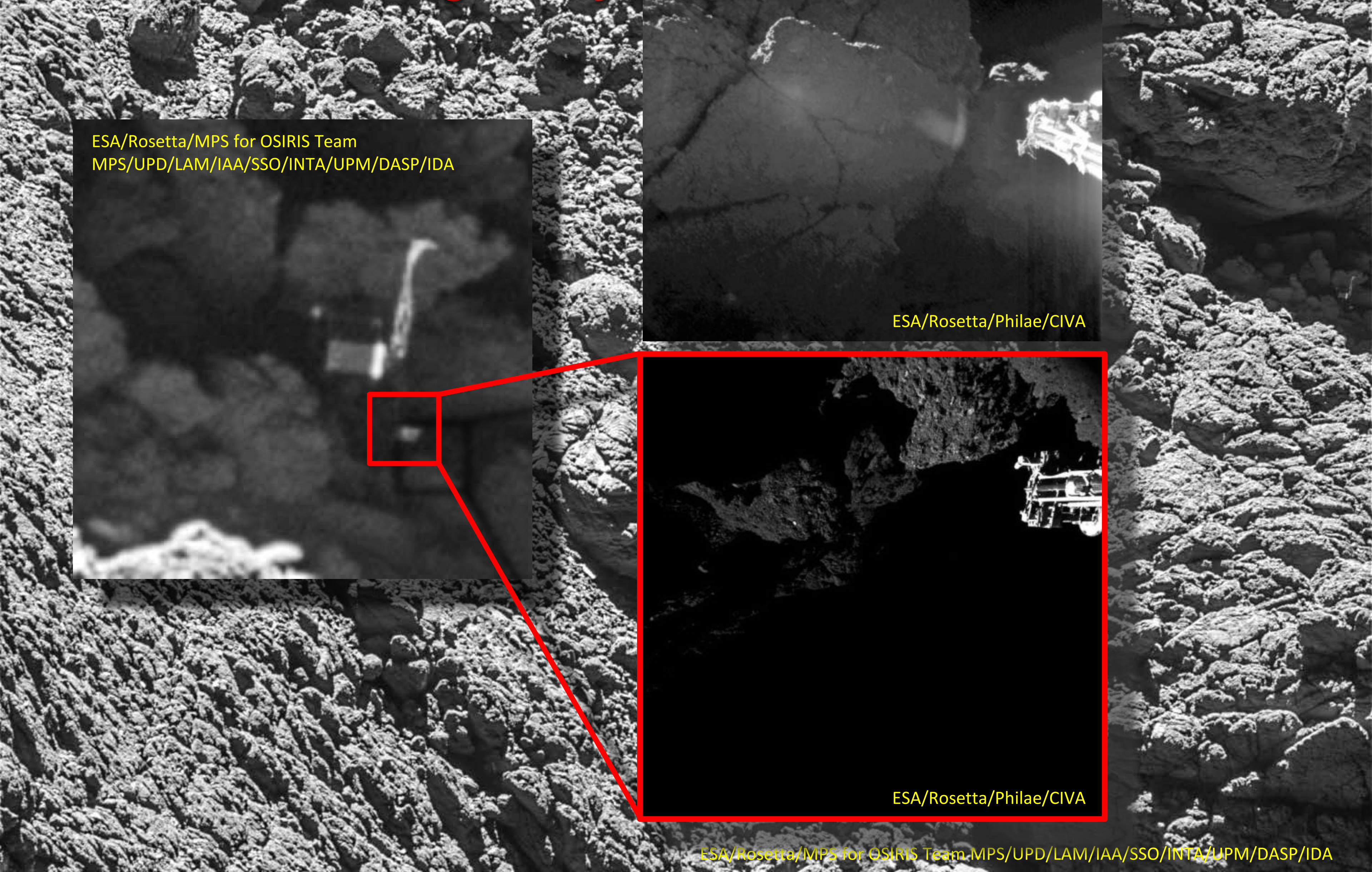

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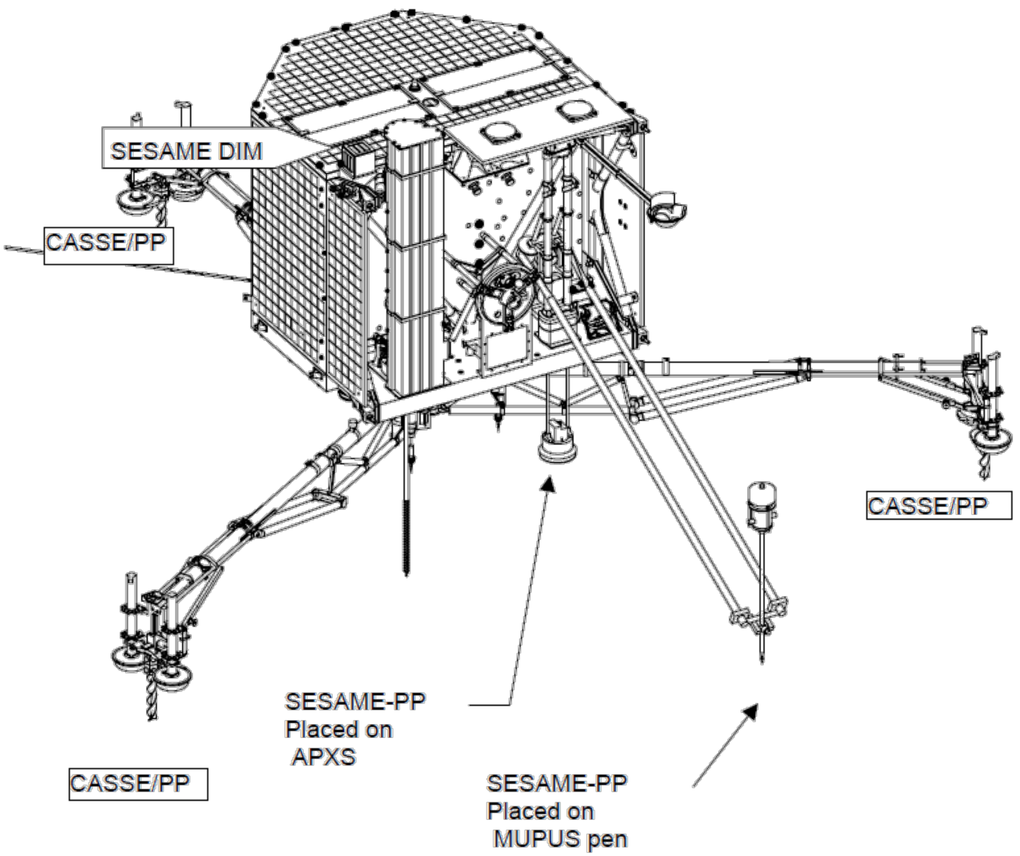
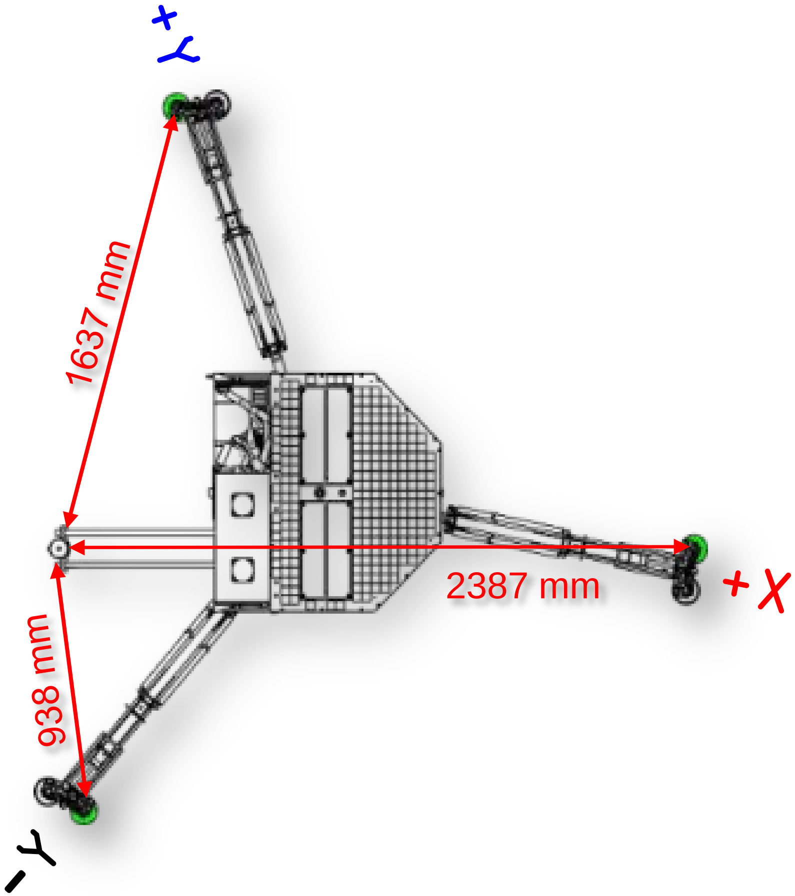




Measure Travel Time

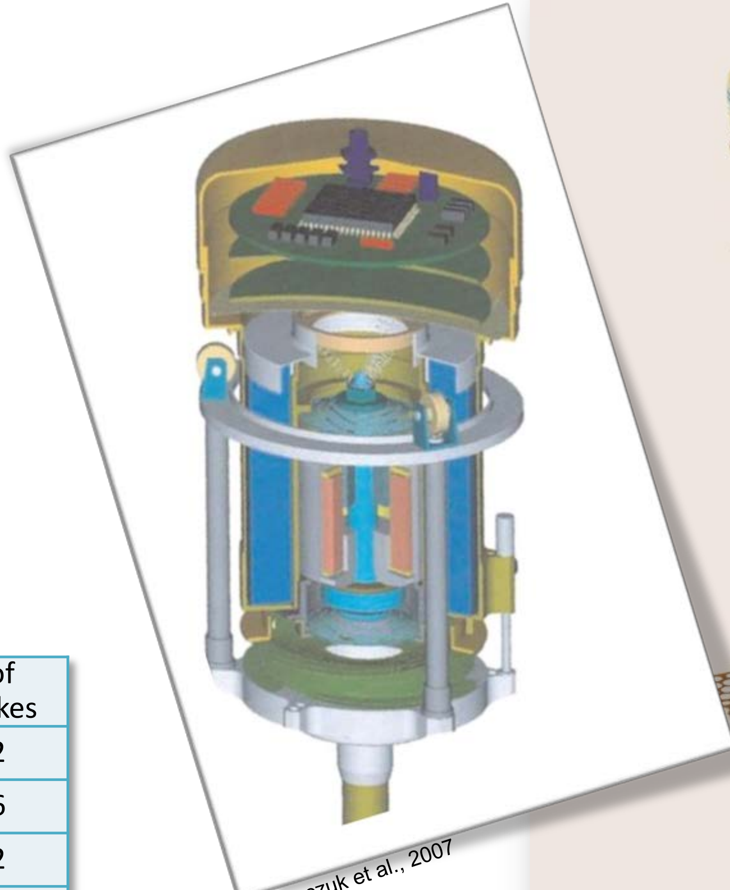
Unknown Topography at Abydos:
Underestimate Distance

⟶ Underestimate Velocity!

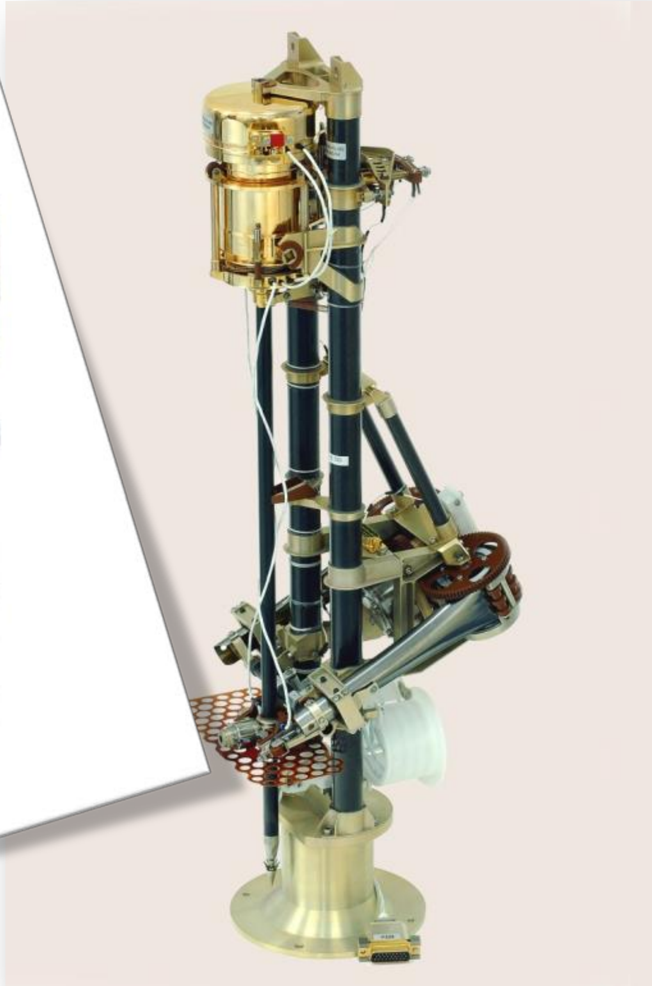
MUPUS Hammering Mechanism

- Coil gun principle: Capacitor discharge via coil accelerates hammer mass
- all active components within MUPUS head
- Stroke times not known precisely

Stroke Level	Energy [J]	Charge Time [s]	4-Stroke Delay [s]	# of Strokes
0	0.5	1.4	14.5	12
1	1.6	4.9	28.4	16
2	2.2	6.2	33.5	32
3	4.2	12.2	57.9	249



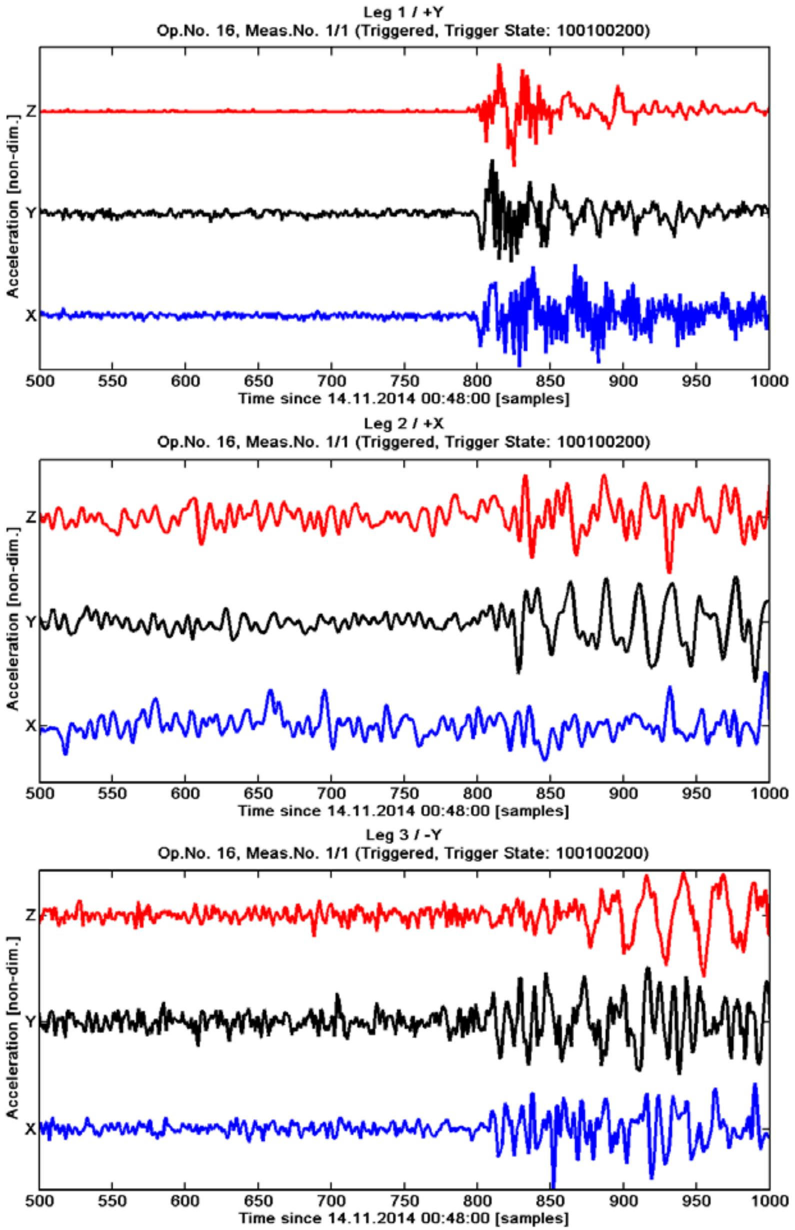
Grygorczuk et al., 2007



Centrum Badań Kosmicznych PAN / Space Research Center PAS

Sample Data

- 14 hammer strokes recorded
- Signal dominated by **Rayleigh wave**
- 8 of these visible on more than one foot
- +Y foot typically the best
- -Y foot typically the weakest
- **65 arrival times** extracted
- lower bound of shear wave velocity of 83 m/s results



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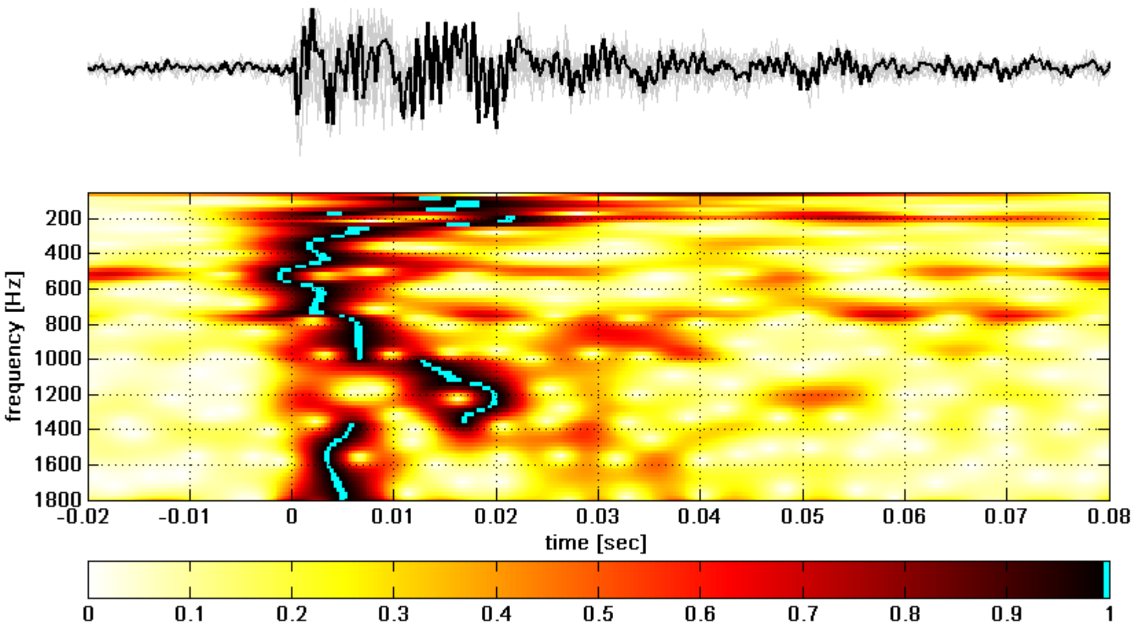
Layering

- Frequencies below ca. 250 Hz arrive approx 10 ms later than higher frequencies

This translates into

- An upper layer $\geq 10\ cm$ thick
- Velocity in top layer is increased 30 % or more compared to deeper material



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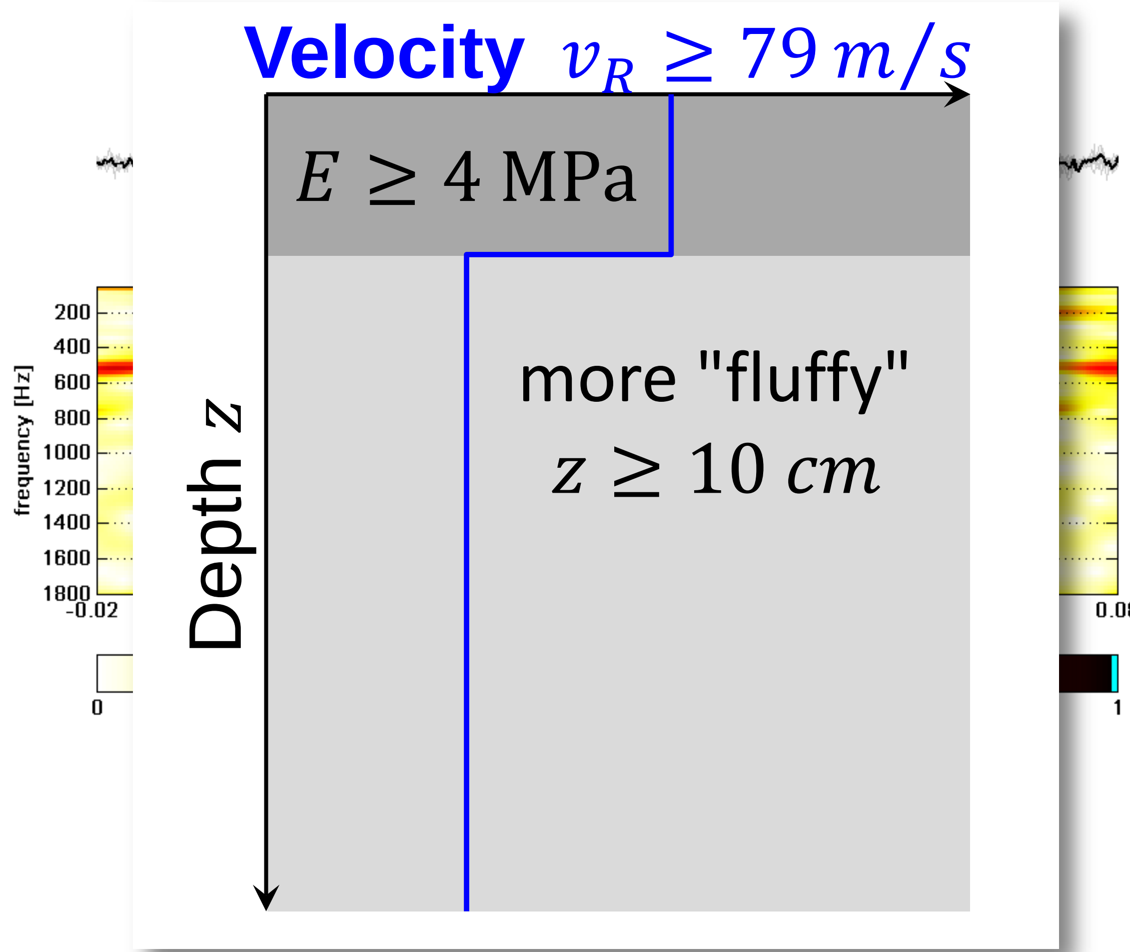
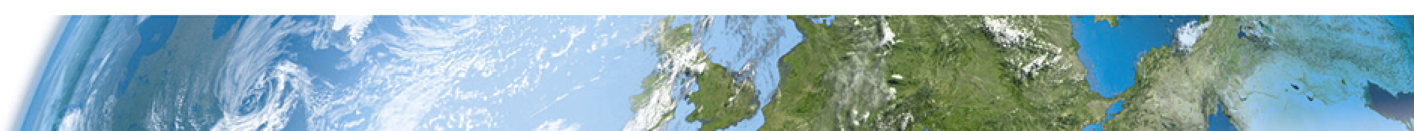
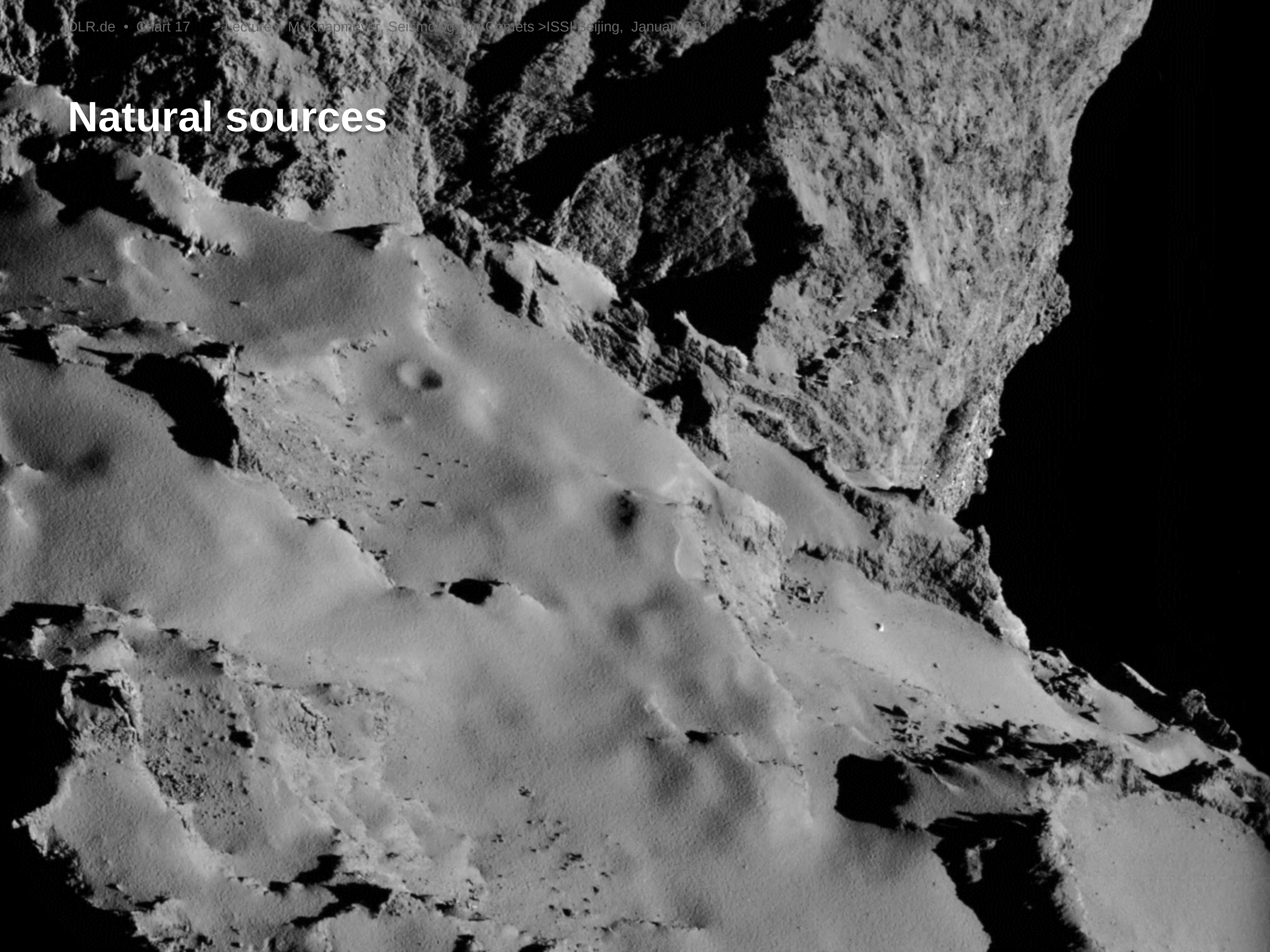




Natural sources



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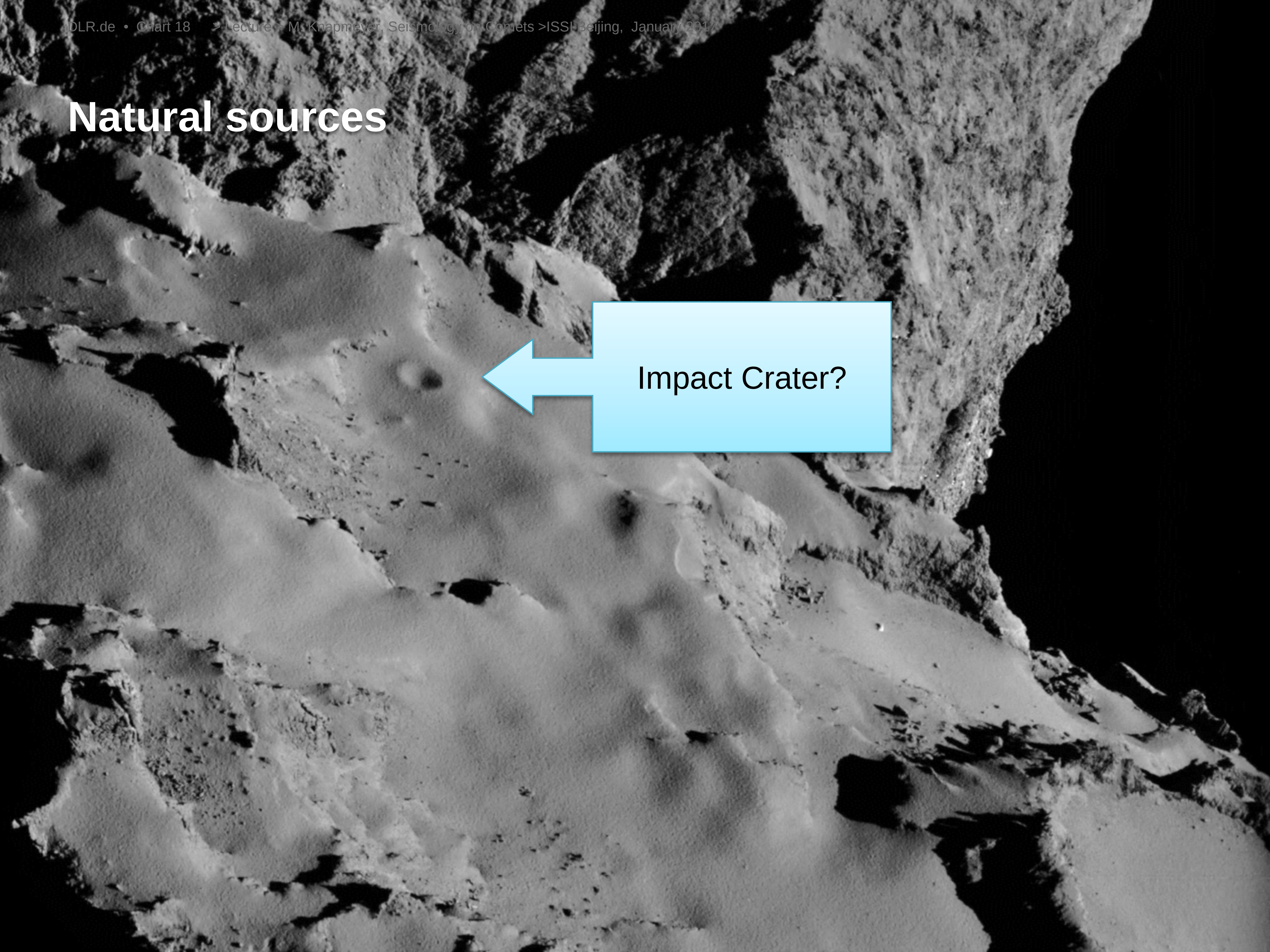


Natural sources

29. July 2015

13:06

13:24

13:42

Natural sources

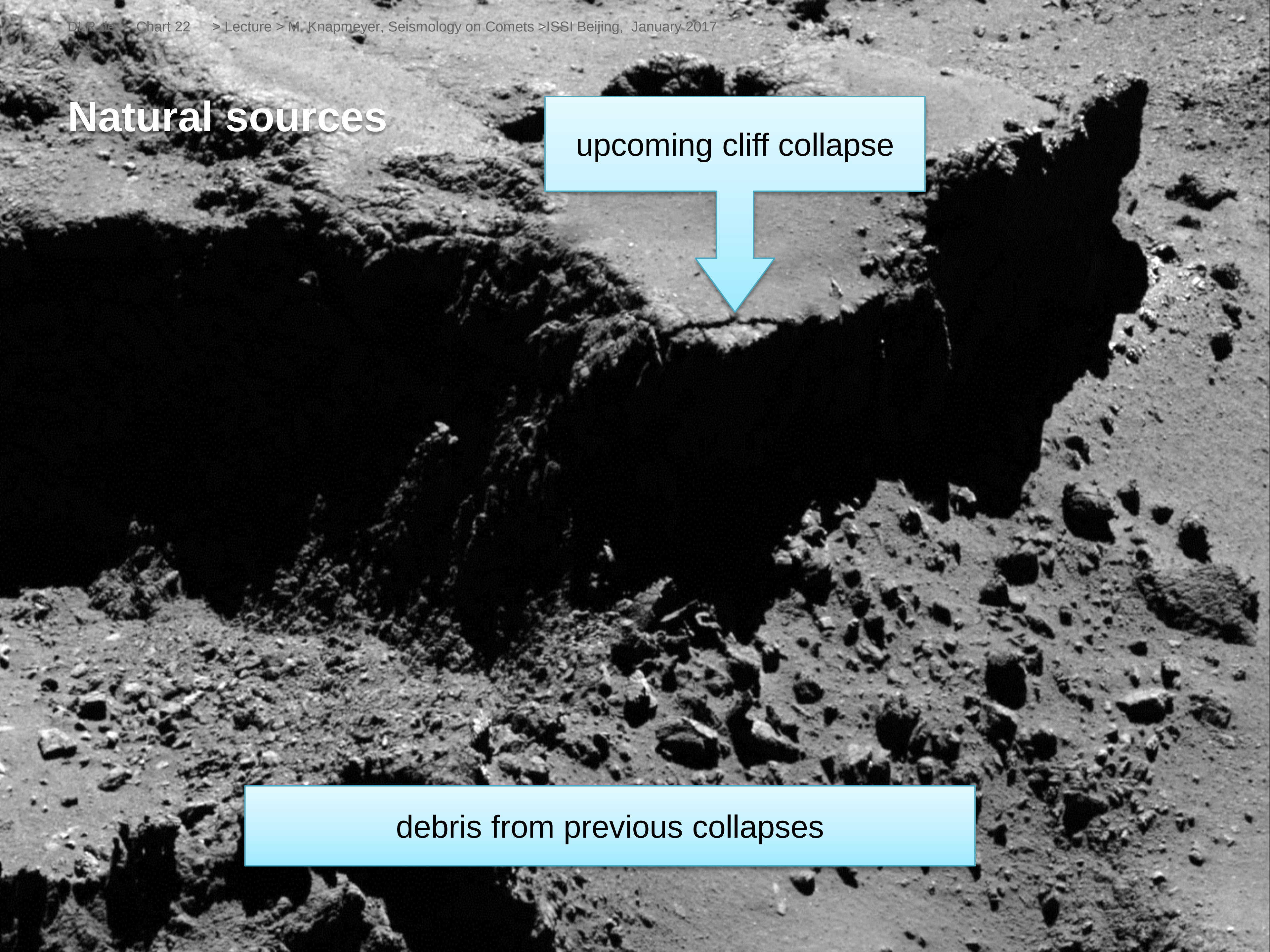
29. July 2015

Tea Kettle Whistle ?

13:06 13:24 13:42

Natural sources

Natural sources



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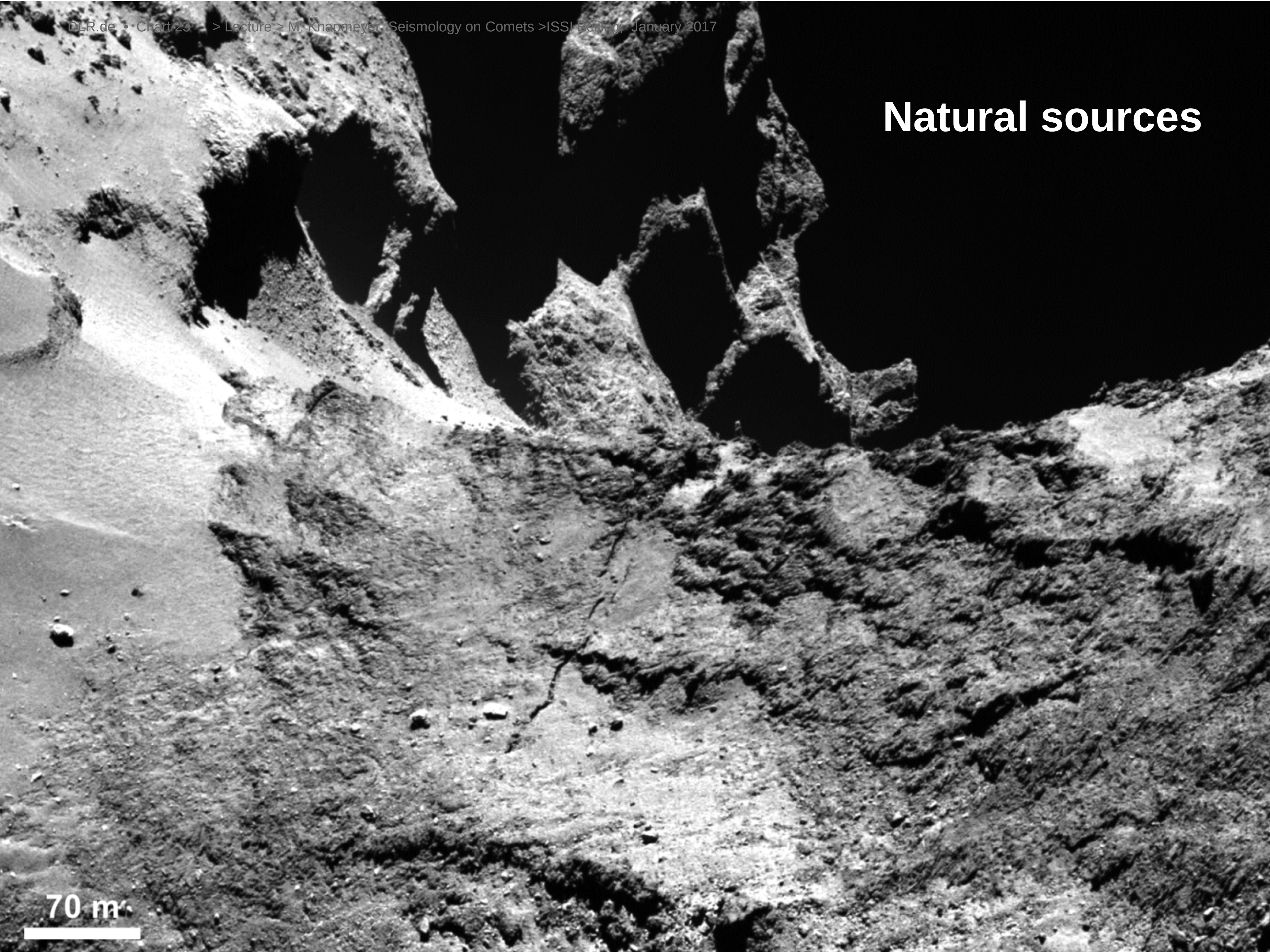

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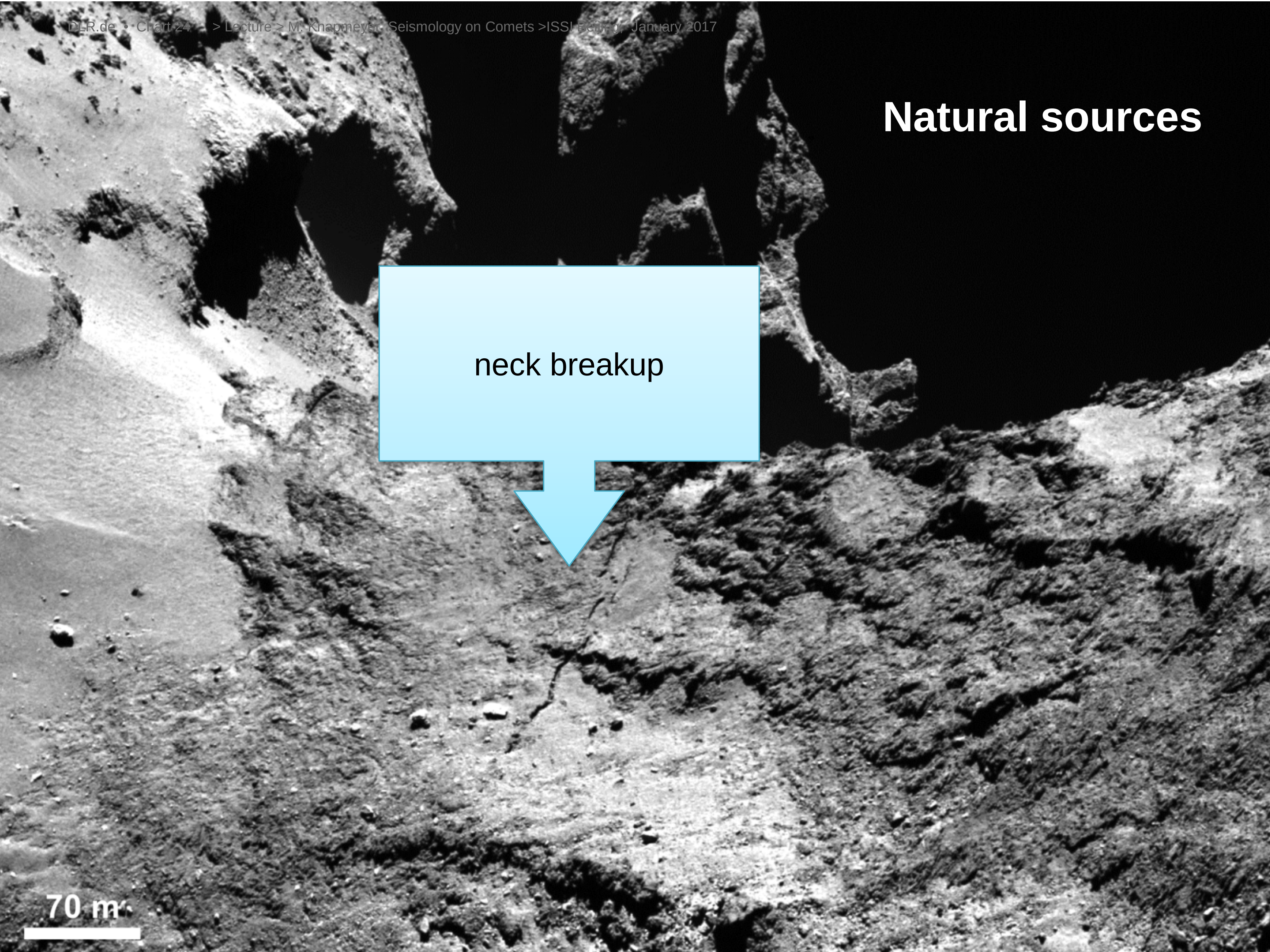


Summary

- We conducted the first active seismic experiment on a comet, at 500 Mill. km distance from Earth: the farthest-out seismic experiment ever

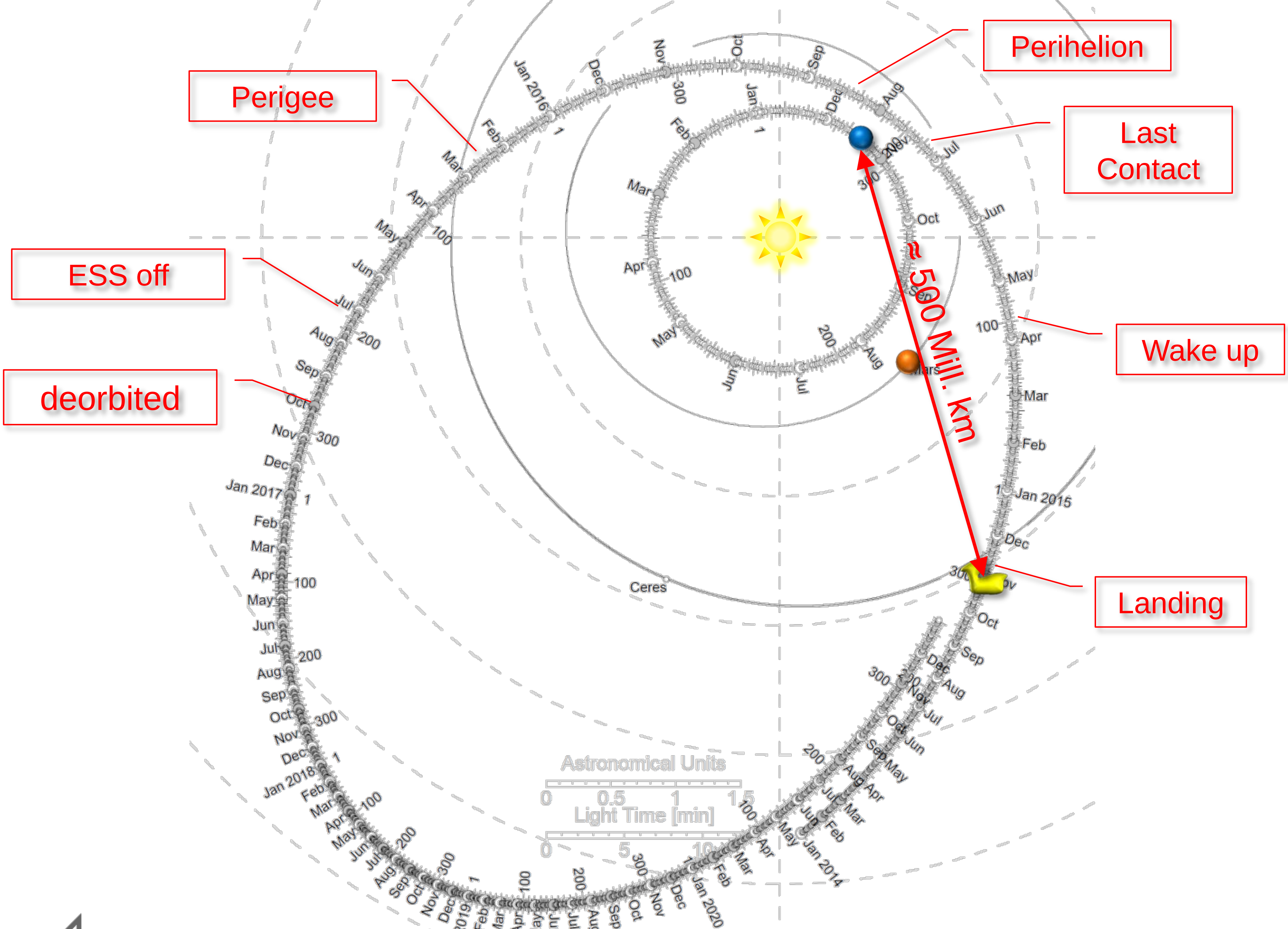
- Specific technical challenges due to distance, spacecraft size, and environment

- Industrial triaxial accelerometers as seismic sensors
- Usable signals from touchdown and hammering of MUPUS
- Touchdown evaluation suggests a Young's modulus of a few 10 MPa
- MUPUS hammering suggests shear modulus of at least 3.6 MPa, and probably less than 331 MPa for a top layer of few decimeters thickness
- Below, shear modulus is reduced by 30 % or more

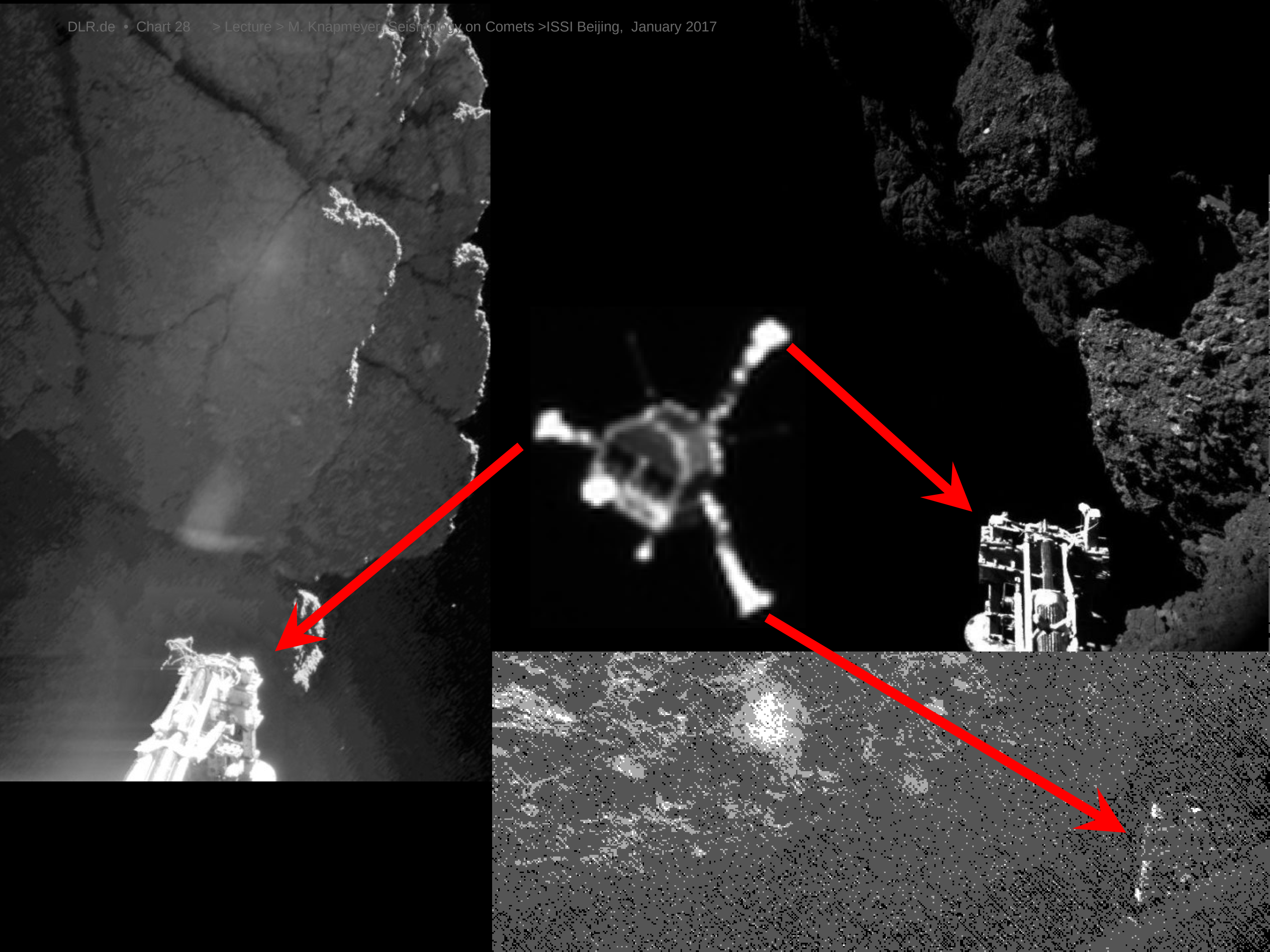
- Comets appear to offer a variety of potential natural sources, like impacts, a possible tea-kettle-like whistling in active regions, cliff collapse and mass wasting, and comet breakup

DLR

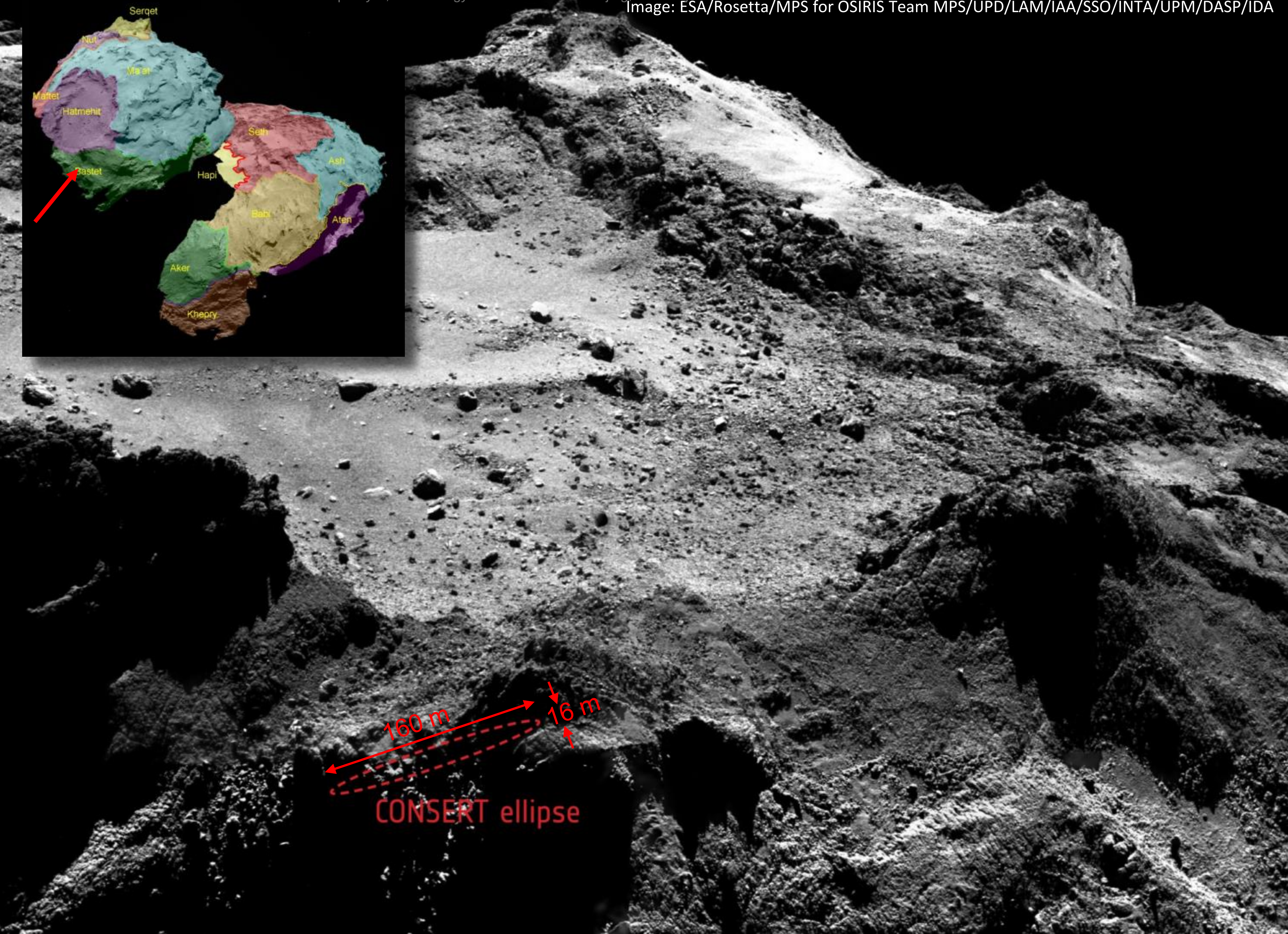
Backup Slides



Perigee
Perihelion
Last Contact
ESS off
Wake up
deorbited
Landing
≈ 500 Mill. km
Ceres
Astronomical Units
Light Time [min]



Ellipse: ESA/Rosetta/Philae/CONSERT
Image: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA



Agilkia Touchdown: Scenarios